Real-time cardiovascular phase-contrast flow MRI during Valsalva Maneuver

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Target Audience: Cardiovascular magnetic resonance, MR flow and motion quantitation.

Purpose: Physiological stress tests, commonly used along with exercises, are considered to be early diagnostic indicator for potential cardiovascular diseases. The Valsalva Maneuver is a physiological stress test where the effect of increase in intra thoracic pressure on cardiovascular flow parameters for a short time span is studied [1]. Echocardiography is the most preferred technique to study the flow parameters obtained from Valsalva maneuver. Phase Contrast (PC) MRI is an established method used for quantitative flow studies. Significant advancements have been made recently with respect to real-time PC MRI using undersampled radial FLASH and nonlinear inverse reconstruction [2]. The aim of this study was to demonstrate the application of real-time PC MRI to obtain qualitative and quantitative flow information from maneuvers such as Valsalva.

Materials and Methods: Normal healthy volunteers (n=6) between the age group 20-30 years were taken for the study. Written consent was obtained before the experiments according to the local ethics committee recommendations. Studies were performed on a 3T MRI system (TIM Trio, Siemens Healthcare, Erlangen, Germany) with MRI signals acquired in supine position using 32 channel cardiac coil with 16 anterior and posterior element arrays. A real-time velocity encoded radial FLASH phase contrast sequence was used to measure through plane flow. The highly undersampled signal acquisition was obtained with scan parameters VENC 200 cms^{-1}, TR/TE/α 2.86ms/1.93ms/10°, in-plane resolution 1.3 mm, slice thickness 6 mm, FOV 192 mm, 2 × 7 spokes, 40 ms temporal resolution. Phase contrast maps were obtained using regularized nonlinear inversion reconstruction. A continuous series of 1000 images with respective ECG time stamps covering a period of 40 s were recorded during the entire experiment, consisting of 1) preparation phase of 10 s, 2) maneuver phase of 10 s and 3) rest phase of 20 seconds. All subjects were instructed to maintain an intra-thoracic pressure of about 40 mmHg during the maneuver phase. As a control parameter, real-time visual feedback of intra-thoracic pressure readings was given to the subject. Flow parameters such as peak velocity and stroke volume of individual heart beats were analyzed for the ascending aorta using QFlow 5.4 Prototype analysis tool (Medis Medical Imaging Systems BV, Leiden, Netherlands).

Results and Discussion: The magnitude images and phase contrast maps for preparation, maneuver and resting phases are shown in figure 1. Differences between magnitude and phase contrast maps can be observed visually for different maneuver phases of the experiment. Variations in flow parameters of ascending aorta as shown in figure 2 are observed due to the high temporal resolution (40 ms) obtained from real time PC imaging. The velocity (spatial average over ascending aorta) reduces by a factor of 2 during the maneuver phase which recovers to normal values during the rest phase. Similarly, the stroke volume also varies by factor of 2 with respect to heart cycles. Heart rate increases during the valsalva maneuver phase having a direct influence on stroke volume. The influence of respiratory cycle on modulation of velocity and stroke volume values can be observed during preparation and rest phase of maneuver.

Conclusion: Complex maneuvers such as Valsalva were until now possible to visualize mainly using echocardiography. The use of real-time PC MRI combining undersampled radial FLASH and nonlinear inverse reconstruction for Valsalva maneuver has been demonstrated. The variability of flow parameters during the maneuver indicates the importance of real-time PC MRI for flow studies. These physiological variations (due to respiration and maneuver) in flow parameters cannot be observed using Cine PC MRI and therefore through this study we have demonstrated that real-time PC MRI can be an ideal tool for understanding the complex maneuvers. It is hypothesized that Valsalva maneuver can be performed only by healthy individuals due to high intra-thoracic pressure built up at short time span. Therefore this method may serve as an early diagnostic parameter for cardiovascular diseases.

References:

[1] Parisi AF et al. Circulation. 1976; 54:921-927.

[2] Joseph AA et al. NMRBiomed. 2012, 25:917-924.

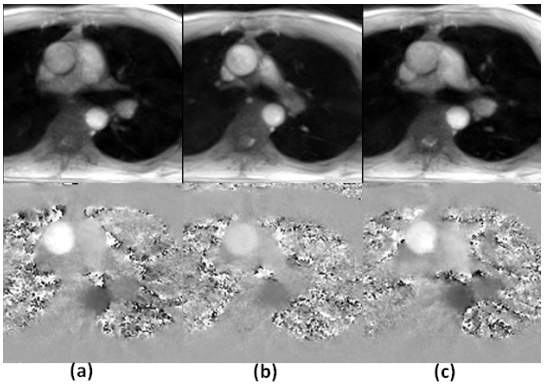

Figure 1: Magnitude and phase contrast maps obtained for (a) preparation, (b) maneuver and (c) resting phase.

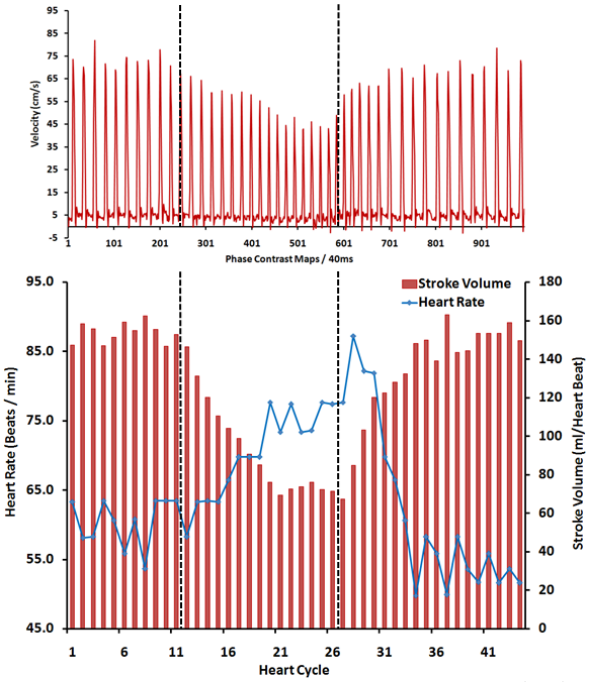

Figure 2: Flow parameters obtained in ascending aorta. (Top) Spatial average of velocities represented over time. (Bottom) Stroke Volume per heartbeat (cycle) and RR interval times obtained over heart cycles. Vertical lines indicate different phases of the measurement.